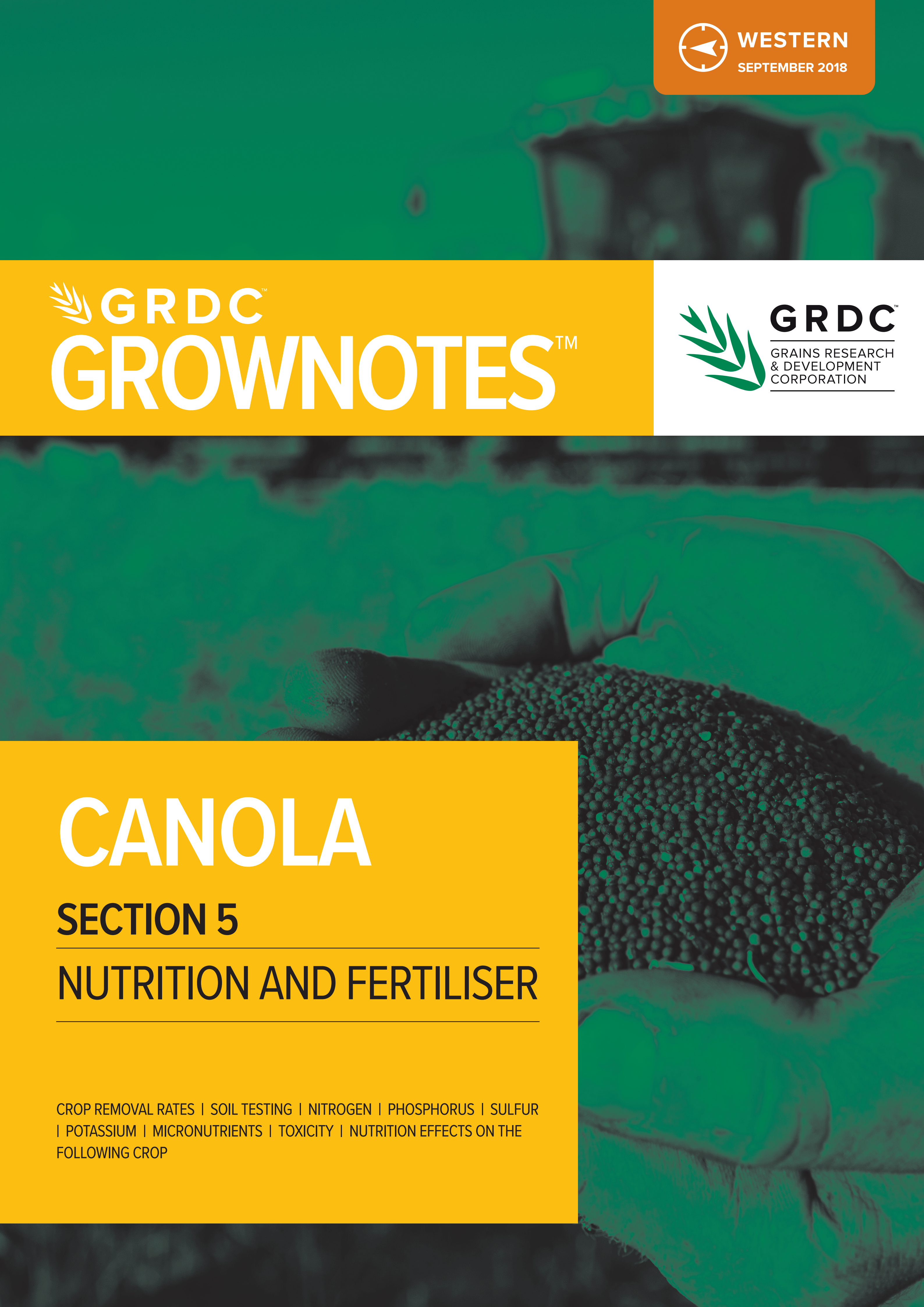


WESTERN
SEPTEMBER 2018

GRDC
GROWNOTES™

GRDC™
GRAINS RESEARCH & DEVELOPMENT CORPORATION

CANOLA

SECTION 5

NUTRITION AND FERTILISER

CROP REMOVAL RATES | SOIL TESTING | NITROGEN | PHOSPHORUS | SULFUR | POTASSIUM | MICRONUTRIENTS | TOXICITY | NUTRITION EFFECTS ON THE FOLLOWING CROP

SECTION 5

Nutrition and fertiliser

FAQ

More information

GRDC Update Papers: Fertiliser strategies, drones and apps

GRDC Update Papers: Shifting investment from nutrients to lime and cultivation on acid soils: is an immediate payback possible?

GRDC Update Papers: Managing nutrition on soils that have been treated for water repellence by cultivation

DAFWA: Focus paddocks 2014 trial report

Research paper: Crop nutrition—canola

CSBP Fertilisers: Soil and plant nutrition

DAFWA: Crop nutrition—frequently asked questions

5.1 Crop removal rates

Canola requires high inputs per tonne of grain for the major macronutrients nitrogen (N,), phosphorus (P, K) and sulfur (S) compared with other crops (Table 1). However, on a per-hectare basis, the nutritional requirements of canola and cereals are similar, because yields are usually about half those of wheat. [1]

Table 1: Comparison of the average quantity of major nutrients removed (kg/ha) per tonne of grain and stubble for a range of crops, including canola and wheat

	Nitrogen		Phosphorus		Potassium		Sulfur	
	Grain	Stubble	Grain	Stubble	Grain	Stubble	Grain	Stubble
Canola	40	10	7	2	9	26	3.5-5	3.2
Wheat	21	8	3	0.7	5	21	1.5	1.5
Barley	20	7	2.5	0.7	4.5	18	1.5	1.5
Oats	20	7	2.5	0.6	4.5	18	2	1
Lupins	51	10	4.5	0.4	9	16	3	2.5

5.2 Soil testing

In Australia, canola is not recommended for sowing on soils of pHCaCl <4.5, and preferably not <4.7 if exchangeable aluminium (Al) levels exceed 3%. Many soils where canola is grown have a pH <5.0; some have pH as low as 4.0. Although most of these soils were naturally acidic, their acidity has been increased by agricultural activities. The acidity may occur in the surface soil or subsoil, or in both. Soil tests for pH are recommended before growing canola. Samples are taken from the surface (0–10 cm), as well as at depth (10–30 cm) to check for subsoil acidity.

Where the soil pH is ≤5, Al and manganese (Mn) toxicities can be a problem for canola. Aluminium is much more detrimental than Mn because it kills root tips, the sites of root growth. Plants with Al toxicity have a shallow, stunted root system that is unable to exploit soil moisture at depth. The crop does not respond to available nutrients, and seed yield is drastically reduced. Severe Mn toxicity reduces yield because entire leaves become chlorotic and distorted. Mild to severe Mn toxicity is often seen sporadically or in patches and often associated with waterlogged parts of fields. [2]

[1] P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

[2] P Hocking, R Norton, A Good (1999) Crop nutrition. In 10th International Rapeseed Congress. GCIRC, http://www.regional.org.au/au/gcirc/canola/p-05.htm

More information

[DAFWA: Canola](#)

[GRDC Update Papers: Use soil test to inform change from phosphorus build-up to maintenance for more profits](#)

[GRDC Update Papers: Economics and management of P nutrition and multiple nutrient decline](#)

[IPNI: Nitrogen and sulfur for wheat and canola—protein and oil](#)

[GRDC: More profit from crop nutrition](#)

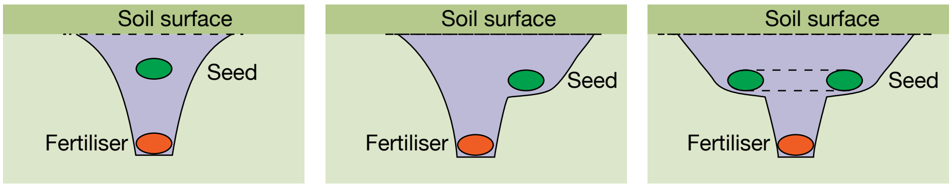
5.3 Nitrogen

Canola has a high demand for N. A canola crop of 1 t/ha will remove ~40 kg N/ha, but the crop will require at least twice this amount. A crop with a targeted yield of ~2 t/ha will require at least 160 kg N/ha. This can be supplied through soil reserves, but additional N fertiliser will be needed in many cases. Depending on the amount of soil N available to the crop, ~80–100 kg/ha of fertiliser N would be needed. In general, a canola crop requires an amount of N similar to a high-protein wheat crop.

Deep soil testing for N and S is recommended for all growers, particularly first-time growers. This will allow N budgeting.

Canola seed is very sensitive to fertiliser burn. No more than 10 kg/ha of N should be in direct contact with the seed at sowing in narrow (18-cm) rows, and proportionally less at wider row spacings. The majority of the N should be either drilled in before sowing or banded 2–3 cm below and beside the seed at sowing (Figure 1). An alternative is to apply N to the growing crop. Application timing should aim to minimise losses from volatilisation; that is, time the topdressing for when the crop has good groundcover and before a rain event. Losses can be high on dry, alkaline soils. [3]

[3] L Serafin, J Holland, R Bambach, D McCaffery (20092005) Canola: northern NSW planting guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0016/148300/canola-northern-NSW-planting-guide.pdf



A. Single outlet with centre banding
Pros: Sub-seed soil disturbance, fertiliser separation banded at depth.
Cons: High draft and breakout force required compared with tillage at seeding depth, seed placement quality variable.

B. Single outlet with side banding
Pros: Sub-seed soil disturbance, fertiliser separation banded at depth, improved seed placement, good moisture transfer to seed.
Cons: High draft and breakout force required, potentially higher soil and residue disturbance.

C. Dual outlet paired row and ribbon sowing systems
Pros: Sub-seed soil disturbance, fertiliser separation, good seed placement except over centre section, higher seed-bed utilisation.
Cons: High draft and breakout force required, higher soil and residue disturbance influencing seeding depth uniformity.

Figure 1: Three arrangements of split seed and fertiliser banding with tillage below the seeding point that illustrate the different types of seed and fertiliser separation achieved.

The N content of a canola plant (expressed as percentage of dry matter) is highest at the full rosette stage; this is when deficiency symptoms are often visible.

Generally, the older leaves become pale green to yellow, and may develop red, pink or purple colours (Figure 2). Plants will be stunted and the crop will not achieve full groundcover by 8–10 weeks after sowing. Once stem elongation commences, deficiency is then characterised by a thin main stem and restricted branching. This results in a thin and open crop. Flowering will occur over a shorter period, reducing the number of pods per unit area.

Figure 2: Nitrogen deficiency symptoms show as smaller leaves, which are more erect, and leaf colours from pale green to yellow on older leaves and pinkish red on others. (Photo: S. Marcroft, MGP)

Some visual symptoms are similar to other nutrient deficiencies (e.g. P and S), and this can result in incorrect diagnosis. [4] Nitrogen deficiency affects older leaves first, whereas S deficiency affects younger leaves first. [5]

Tissue tests, combined with a good knowledge of the paddock history (including past fertiliser use and crop yields), will assist in an accurate assessment of the most likely deficiency. [6]

DAFWA: Diagnosing nitrogen efficiency in canola

GRDC Update Paper: Getting nitrogen (N) into the crop efficiently and effectively

5.3.1 Estimating nitrogen requirements

Canola is ideally grown in soils of high N fertility, for example, as the first or second crop following a legume crop or two years of legume-dominant pasture. However, paddock fertility is often inadequate, so additional N is required to produce both high yields and good seed quality.

Although canola removes 40 kg N/t grain, the crop can require at least twice this amount of N to produce the yield (referred to as the efficiency factor). This is because the plants must compete for N with soil microorganisms, and some of the N taken up by the plants is retained in the stubble and senesced leaves and roots. A good canola crop will produce twice as much stubble as grain (by weight), giving a harvest index (HI) of about 33%.

The best way to determine a crop's potential N requirement is through a combination of N removal (total N in the estimated grain yield efficiency factor) and the amount of N estimated to be available in the soil, utilising 0-10cm soil (testing for Organic Carbon, Nitrate and Ammonium Nitrogen) and deep soil testing . Whilst not a common practice yet in WA, deep soil tests (to a depth of 60 or 90 cm) can be taken prior to sowing and enable fine tuning of the crops N requirements. They can also be done during the growing season to determine whether topdressing is required.

4 P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

5 Diagnosing nitrogen deficiency in canola, https://www.agric.wa.gov.au/mycrop/diagnosing-nitrogen-deficiency-canola DAFWA (2015) Diagnosing nitrogen deficiency in canola. Department of Agriculture and Food Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-nitrogen-deficiency-canola

6 P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

Example

Available soil N (calculated from deep N test + estimate of in-crop mineralisation) = 125 kg/ha

As a rough 'rule of thumb', the in-crop mineralisation is calculated as:
Growing season rainfall (mm) x organic carbon (%) x 0.15

Fertiliser N required for crop = total N required – available soil N (kg N/ha)
= 200 – 125 kg N/ha
= 75 kg N/ha

Nitrogen requirement calculator

Nitrogen removed in grain = target yield x 40 (kg N/t grain)

Total N required = N removed in grain x 2.5 (efficiency factor of 40%)

In the example:
Estimated target yield = 2 t/ha
N removal in grain 2 x 40 kg N/t = 80 kg N/ha
Total N required = 80 x 2.5 kg N/ha
= 200 kg N/ha [7]

More information

GRDC/Federation University: Online Farm Trials research

5.3.2 Diagnosing nitrogen deficiency in canola

Nitrogen deficiency is the most common nutrient deficiency in canola, especially during cold, wet conditions and in sandy soils in high-rainfall areas. Hybrid varieties can display leaf purpling with adequate nutrient levels (Figure 3).

7 P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

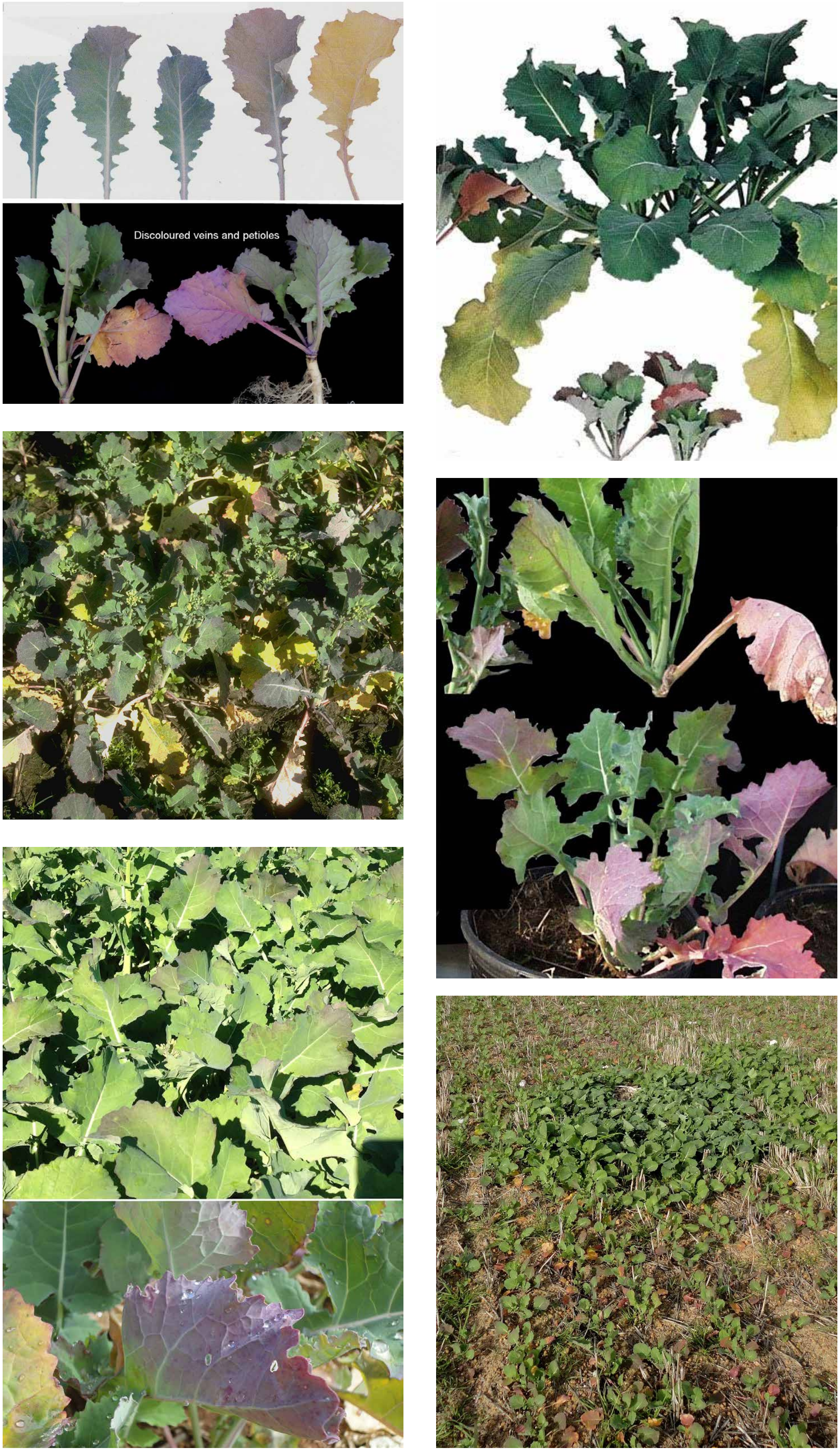


Figure 3: *Images of nitrogen deficiency in canola. (Photos: DAFWA)*

What to look for

Paddock

- Plants are smaller and less branched with red to purple or yellow leaves.
- Symptoms are worse in wetter seasons, on lighter soil areas and sometimes on non-legume header rows.

Plant

- Mildly deficient plants are smaller with paler green and more erect leaves. Deficient seedlings have reddened cotyledons.
- Oldest leaves develop whitish purple veins and mild purple pigmentation, which starts at the end of the leaf and progresses to the base on both sides of the leaf. (See Table 2 for conditions with similar leaf symptoms.)
- The whole leaf then turns yellow or pinkish purple. Developing leaves are narrow and more erect.
- Established plants that become N-deficient develop yellowing on leaf margins that spreads in toward the midrib between the veins. The midrib becomes discoloured then the leaf dies.
- From stem elongation, the main stem is thinner and branching is restricted. Flowering time and pod numbers are reduced.

What else could it be?

Table 2: Conditions that result in symptoms in canola similar to nitrogen deficiency. Other conditions may include K deficiency or Alternaria.

Condition	Similarities	Differences
Beet western yellow virus in canola	Purple-red colours spreading from end of oldest leaves	Affected plants are stunted rather than smaller and thinner as in N deficiency
Damping off in canola	Reddened cotyledons and older leaves of seedlings	Damping off causes stunted plants with pinched roots or hypocotyls. Often plant death occurs
Sulfur deficiency in canola	Purple leaves	Sulfur deficiency affects younger leaves the most
Phosphorus deficiency in canola	Purplish older leaves	Phosphorus-deficient plants have purpling on leaf margin, then the leaf turns bronze

Where does it occur?

Nitrogen deficiency can occur on most soils but is most common in the following situations:

- cold, wet conditions that slow N mineralisation and uptake of N
- soils with very low organic matter
- after high rainfall on sandy soils, which can result in nitrogen leaching

Management strategies

- Granular or foliar Nitrogen fertiliser can be applied. However with foliar N, a low percentage N can only be absorbed through the leaf, so you will still be reliant on rainfall to move the N into the root-zone. Consider economics. Economics of liquid *v.* solid fertilisers as liquid N is often more expensive per unit of N.

- There is a risk of volatilisation loss from urea or nitrate sources of N. Loss is greatest from dry alkaline soils with dewy conditions, but recent GRDC-funded research shows this may not be as high as traditionally thought. [8]
- The yield potential for canola is established during stem elongation and the budding stage, so all N should be applied before this stage of growth (8–10 weeks).

Tissue test

- Use whole top-of-plant test to diagnose suspected deficiency. Critical N levels vary with plant age and size, but as a rough guide, 2.7% (seedling) to 3.2% (rosette) indicates deficiency.
- Nitrogen soil testing by itself is of little value for most soils.
- Models that combine nitrate, ammonium, soil organic carbon, soil type, and legume history are valuable for N fertiliser calculation.
- Leaf-colour symptoms are not a reliable guide for hybrid varieties. [9]

infocus

5.3.3 Timing of nitrogen for canola in lower rainfall areas in Western Australia

Key messages

In 2013, application of N at seeding or at 4, 8 or 12 weeks after sowing provided similar responses. In low-rainfall areas, as N supply increases, the oil percentage of canola often decreases at a faster rate than grain yield increases. In most instances, Roundup Ready® (RR) canola produced higher grain yields, oil percentage and gross margins.

Timing needs to be drawn out to later full flower timing in many areas that have adequate moisture. There is still a linear response to N at this late timing, especially on higher leaching soils. Much of the research stopped at stem elongation and early flowering as it became too hard to apply the later timing. The data is true for low rainfall environment but not higher rainfall.

Agronomist's view

Aims

The aim was to investigate the N rate and time of application response of canola in lower rainfall parts of Western Australia (WA).

8 G Schwenke (2014) Nitrogen volatilisation: Factors affecting how much N is lost and how much is left over time (2014), GRDC Update Papers, 25 July 2014, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Factors-affecting-how-much-N-is-lost-and-how-much-is-left-over-time

9 DAFWA (2015) Diagnosing nitrogen deficiency in canola. Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-nitrogen-deficiency-canola

Method

Nine experiments were conducted in lower rainfall areas in 2013 and eight in 2014, which compared elite hybrid and open-pollinated (OP) cultivars incorporating triazine-tolerant (TT) and RR herbicide technologies. The 2013 trials are reported. Nitrogen treatments in 2013 included five rates of N (0, 25, 50, 75 and 100 kg N/ha) applied as per schedule in Table 3. Gross margins were calculated taking into account grain and seed prices and herbicide costs for RR and TT varieties, oil bonuses, N fertiliser and application costs, and all other associated input costs.

Table 3: Nitrogen treatments in canola trials in 2013

Total N applied (kg/ha)	Timing of N application(s) (weeks after seeding)	Treatment name (N applied)
0	0	0N
25	0	25N
25	4	0N 25N
25	8	0N 0N 25N
25	12	0N 0N 0N 25N
50	0	50N
50	4	0N 50N
50	8	0N 0N 50N
50	12	0N 0N 0N 50N
50	0 + 4	25N 25N
50	0 + 8	25N 0N 25N
50	0 + 12	25N 0N 0N 25N
75	0 + 4 + 8	0N 50N 25N
100	0 + 4 + 8	25N 50N 25N

Results

Grain yield of canola with no applied N ranged from 0.7 to 1.7 t/ha (mean of both varieties, Table 4). Canola yield and oil percentage responded to applied N at all sites (Table 4). A typical response at Salmon Gums is shown in Figure 4, where oil percentage decreased and grain yield increased with applied N; oil percentage decreased more quickly than grain yield increased, resulting in a flat financial response at rates of applied N >40 kg/ha. Similar responses at other sites resulted in four of nine sites showing no financial gain from applying N.

Grain yield was not affected by time of application of 25 or 50 kg N/ha in eight of nine trials. Oil percentage was not affected by time of application of 25 kg N/ha in eight of nine trials, whereas timing of 50 kg N/ha had a significant effect on oil percentage at the three driest sites (Merredin, Miling North and Salmon Gums). At these sites, applications near flowering (at 12 weeks after sowing) reduced oil percentage in the seed by 0.6–1%, with split applications (25 kg at seeding and 25 kg at 12 weeks after sowing) having less effect than a single application. Despite these reductions in oil percentage with delayed N application, there was little overall effect on timing of N on gross margins (no significant effect in 17 of 18 instances).

In most cases, RR outyielded TT canola and produced higher oil percentages, resulting in higher gross margins for RR in four of nine trials. However, at Salmon

Gums and Merredin, TT canola produced similar yields to RR and therefore had higher gross margins because of lower seed costs.

Table 4: Site details for canola nitrogen (N) application trials in 2013, grain yield (t/ha) with no applied N, 90% of maximum grain yield, and N applied to achieve 90% maximum yield

Location	April to October rainfall (mm)	Organic carbon (%) in top 10cm at sowing	Nitrogen (kg N/ha) in top 30cm at sowing*	N avail.# (kg N/ ha)	Previous crops(2012/ 2011/ 2010)	OP TT and RR hybrid varieties	Grain yield (t/ha) with no applied nitrogen	90% of max GY (t/ ha)	N at 90% of max GY (kg N/ha)
Cunderdin	243	0.86	36	42	barley/ wheat/ pasture	ATR Stingray and Hyola 404RR	0.7	0.9	107
Eradu	280	0.86	80	66	wheat/ wheat/ lupin	ATR Stingray and Hyola 404RR	1.1	1.5	76
Holt Rock	282	1.42	132	71	barley/ barley/ wheat	CB Telfer and Hyola 404RR	1.7	2	52
Katanning	356	2.91	86	139	oats/ lupin/ hay	ATR Stingray and Hyola 404RR	1.5	1.8	60
Merredin	204	0.55	92	60	fallow	CB Telfer and Hyola 404RR	0.8	1	61
Miling North	223	0.47	49	74	wheat/ wheat/ lupin	CB Telfer and Hyola 404RR	0.9	1.1	36
Salmon Gums	217	0.8	31	39	wheat/ barley/ canola	CB Telfer and Hyola 404RR	0.9	1.2	57
Wittenoom Hills	305	1.8	41	104	barley/ wheat/ field pea	ATR Stingray and Hyola 404RR	1	1.5	86
Wongan Hills	227	1.01	150	63	wheat/ pasture/ pasture	ATR Stingray and Hyola 404RR	1.48	1.53	23

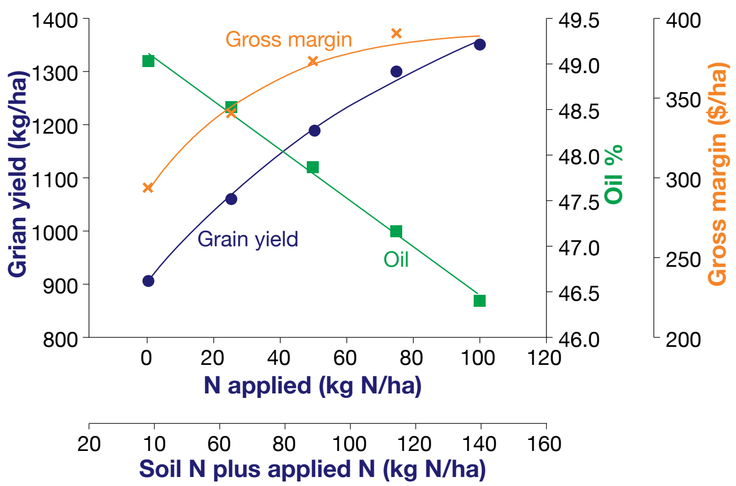


Figure 4: Response of canola grain yield (kg/ha), seed oil (%) and gross margin ($/ha) to increasing nitrogen at Salmon Gums in 2013

Conclusion

In most of the trials conducted in 2013, the timing of N application had no significant effect on grain yield, oil percentage or gross margins. In a few instances, applying N near flowering (12 weeks after sowing) reduced the oil percentage in canola. However, the reductions were often not large enough to reduce gross margins.

It is not common for growers to apply N much later than 8 weeks after sowing. This work suggests that in seasons similar to 2013 with a long soft spring over much of the grain-growing areas, growers can delay their N decisions until early flowering (12 weeks). Thus, farmers can play the season for a few more weeks or 'catch-up' if they missed their regular fertiliser time. [10]

More information

GRDC Fact Sheet: Crop Nutrition Phosphorus Management Fact Sheet

5.4 Phosphorus

Nearly all soils in WA were P-deficient, but continual use of P fertiliser means that acute deficiency in broadacre crops is rare, with the exception of crops on Darling Range gravels. Phosphorus deficiency is often transitory and compounded by dry soil, with symptoms disappearing when topsoil is re-wet following rainfall.

Figure 5: Phosphorus deficiency in canola. (Photo: DAFWA)

What to look for

Paddock

Plants are smaller and less branched, with worse symptoms on higher P-fixing and acidic soils, and in very dry seasons.

Plant

- Deficiency most commonly shows as smaller plants with similar-shaped leaves (Figure 5).
- From stem elongation, the main stem is thinner and branching is restricted.
- Flowering time and pod numbers are reduced.
- Severely deficient plants develop a narrow purple margin of the leaf blade that spreads inwards. (See Table 5 for conditions with similar leaf symptoms.)
- The leaf turns bronze before dying.

[10] M. Seymour, S. Sprigg, B. French, R. Malik, J. Bucat and M. Harries (2015), Department of Agriculture and Food Western Australia, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Timing-of-nitrogen-for-canola-in-lower-rainfall-areas-in-WA

What else could it be?

Table 5: Conditions that result in symptoms in canola similar to phosphorus deficiency

Condition	Similarities	Differences
Beet western yellow virus	Purple–red colours on oldest leaves	Purpling spreads down from the leaf end with *Beet western yellow virus* and affected plants are stunted rather than smaller and thinner. Phosphorus-deficient plants will vary with the soil type
Nitrogen deficiency	Purple–red colours on oldest leaves	Symptoms in nitrogen-deficient plants move from the margins to the base with the leaves turning yellow or pink-purple

Where does it occur?

Phosphorus deficiency is a problem on high P-retaining (high Phosphorus Buffering Index (PBI)) soils, particularly in the Darling Range acidic gravels where soil acidity and water repellence markedly reduce P uptake, and in high pH calcareous clay soils.

Dry topsoil can lead to temporary P deficiency on all soils, particularly during early crop growth and on water-repellent soils.

Water-repellent and acidic soils require more P.

Management strategies

Plants have a high requirement for P during early growth. Phosphorus is relatively immobile in the soil; therefore, topdressed or sprayed fertiliser cannot supply enough to correct a deficiency.

Phosphorus is poorly mobile in most soils, but does move on sands with very low P-buffering index (PBI), particularly on coastal plains. Topdressing is effective on these soils, but deficiency is rare.

Root pruning caused by Al toxicity on acidic soils markedly increases P deficiency.

How can it be monitored?

Use soil tests to determine P fertiliser requirements. Soil tests may underestimate available P on very low PBI sands and overestimate it on acidic and water-repellent soils (particularly in the Darling Range).

Use whole-shoot plant tests to diagnose suspected P deficiency, and compare paired good and poor plant samples where possible. Critical plant P levels vary with plant age and size, but as a rough guide, 0.3% (seedling) and 0.25% (rosette) indicate deficiency. [11]

5.4.1 Role and deficiency symptoms

Phosphorus plays an important role in the storage and use of energy within the plant. Lack of P restricts root development (resulting in weaker plants) and delays maturity; both of these affect yield potential and seed oil content, particularly in dry spring

[11] https://www.agric.wa.gov.au/mycrop/diagnosing-phosphorus-deficiency-canola DAFWA (2015) Diagnosing phosphorus deficiency in canola. Department of Agriculture and Food Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-phosphorus-deficiency-canola

conditions. Low P levels also restrict the plant's ability to respond to N. Even a mild deficiency can significantly reduce plant growth without any symptoms. In cases of severe deficiency, the older leaves will often appear dull blue or purple (Figure 6). Phosphorus is a very mobile nutrient within the plant, and if a deficiency occurs, it moves rapidly from older leaves to the young leaves or developing pods.

Figure 6: Phosphorus deficiency shows as distinct pink purpling of the tips and margins of older leaves. (Photo: P. Hocking, CSIRO)

Fertiliser placement

In the soil, P is immobile, so fertiliser should be banded close to the seed at sowing. This ensures that the developing seedling is able to take up a good supply during the early growth stage when requirement for P is at its highest. Many soils (particularly if exchangeable Al is present) are able to tie up P, making it unavailable to plants. Banding the fertiliser can reduce the amount of P tied up because less fertiliser is in contact with the soil than occurs with broadcasting.

Phosphorus fertiliser banded above and below the seed gives better yield responses than P broadcast before sowing. In sandy soils, which are prone to drying in the surface layer, banding some of the fertiliser below the seed at sowing may improve the efficiency of P uptake.

Phosphorus requirements

If a wheat crop responds to P, then a rate at least equivalent should be used when sowing canola at that site. Topdressing is ineffective, so it is important to get the P rate right at sowing. A maintenance application of 7–8 kg P/ha is needed for every tonne of canola you expect to harvest.

If a soil test indicates a high level of soil P, then lower rates of P could be applied. In some situations, where soil P levels are very high, it may be uneconomic to apply P. If more is applied than is removed by the grain, it will be added to the soil P bank and may be available for following crops or pastures to utilise. However, a significant proportion (up to 50%) of applied fertiliser P can ultimately become 'fixed' into organic and inorganic forms that are largely unavailable for crop uptake in the short–medium term but can add to the P pool in the longer term, with a proportion of the P becoming available over time.

Depending on your location, a few laboratory analyses are available for P. The Olsen-P test (bicarbonate test) is often recommended on acid soils, whereas the Colwell-P test is more useful on alkaline clay soils. However, each of these tests measures only a proportion of the P status of a soil. The PBI (P buffering index) is also important because it can indicate how available the soil P is to plants, and BSES-P is recommended as a baseline of the pool P status (easily available and slow-release pools). A qualified soil nutrition advisor will help you to decide which tests are applicable on your soil type.

More information

EGRDC Update Papers: Economics and management of P nutrition and multiple nutrient decline

If tests indicate <20 mg/kg, then P is considered marginal to low (depending on soil type and rainfall) and a response is likely. If the soil P level is high (>40 mg/kg), a response to P is less likely, unless the soil is acidic (pHCaCl <4.8) and has a low cation exchange capacity (<5 cmol(+)/kg) or the soil is alkaline pHCaCl >8 and highly calcareous.

5.5 Sulfur

Sandy-textured soils in WA are naturally low in S, and applied S is readily leached from the top 10 cm, especially in high-rainfall areas.

The use of fertilisers containing S somewhat masks the low levels of S present in the soil; however, the introduction of more sensitive crops such as canola and the shift to compound fertilisers that are low in S has increased the frequency of S deficiency seen in crops. High rainfall can leach sulfur from the root-zone early in the growing season, leaving young crops deficient. Other factors that can induce deficiency in crops include subsoil constraints such as acidity, sodicity and hardpan, and the level of N in the soil can limit the crop's ability to access subsoil sulfate.

Compared with wheat, canola crops have a high demand for S. Every tonne of canola grain harvested per hectare uses 10 kg S, compared with 1.5 kg S for wheat. The high demand for S in canola is driven by the high protein content and the presence of S-containing glucosinolates in the seed. The concentration of S in the seed, means high rates of removal from the field—about 3.5 to 5 kg S/t harvested canola grain—especially in high-yielding crops.

Canola also has high within-season demand for S compared with the requirements of wheat. Critical values have been identified for both soil and tissue tests in canola; these suggest that canola has higher S-fertiliser requirements.

The mobile nature of S in the soil, and its capacity to be mineralised through the breakdown of organic matter, makes it difficult to predict reliably when a crop will respond to S application.

A synergistic relationship exists between S, N and P, which affects plant uptake and efficient use of these nutrients. Too much N can induce S deficiency in plants. Grain yields increase when all three nutrients are in sufficient supply and in the correct ratio.

Most of the S present in the soil is bound into organic compounds, but plants can take up only the mineral sulfate form. Cultivation releases S held in the organic matter. In no-till systems, soil organic matter breaks down slowly, releasing mineral S for crop use. Sulfur mineralisation is low in cooler months, as is root exploration, which can cause temporary deficiency in crops, seen as patches that disappear when the soil temperature increases. Mineralisation is higher in the warmer months and under moist soil conditions. Sulfate adsorption occurs in the soil layers below 10 cm, and this can make a significant contribution to crop growth once crop roots have reached the subsoil.

The rate of sulfate leaching is highly variable, depending on seasonal conditions and the water-holding capacity of the soil, and is closely related to the rate of nitrate leaching. These two nutrients are best considered together when planning fertiliser applications at seeding and post-seeding to compensate for their movement down the profile under the current seasonal conditions.

Sulfur nutrition in cropping systems is usually managed through the application of P or N fertilisers containing S. Several fertiliser products are available to growers to supply the crop's S requirements. Gypsum and ammonium sulfate are the most common sources of applied S. Gypsum is often preferred; it contains ~16–18% sulfur, is relatively inexpensive, and unlike ammonium sulfate, it is not acidifying. There are other fertilisers with varying N : S ratios achieved by blending ammonium sulfate with urea or adding S to UAN (urea–ammonium nitrate) products such as Flexi N. Blending ammonium sulfate with urea creates a product that absorbs water from the atmosphere, making it difficult to store and handle.

On sandy soils in WA, only 15% of applied S remains in the top 0.5 m one year after application. Gypsum-S applied at 34 kg S/ha to pasture grown on a non-leaching clay loam in WA has achieved a residual benefit to dry matter production for up to 3 years, but this is unlikely to occur on sandy soils.

Iron, aluminium oxides and alkaline soils have the capacity to bind S and reduce leaching; however, the bound S will not be available to plants. [12]

5.5.1 Deficiency in canola

Sulfur is critical for high canola yields, and deficiency is detected at all growth stages. When supply of S is low, there is limited movement of S within the plant, so new leaves, flowers and pods are likely to be more deficient than older leaves and pods. When S and water are adequate, it can translocate within the plant as required. Adequate–high N availability limits the movement of S within plants and deficiency symptoms may be seen on younger leaves.

The maximum response to S is at rates of 10–20 kg/ha on very S-deficient soils. Remember the need to balance N and S levels.

12 GRDC (2015) Sulfur strategies for western region. GRDC Media Centre, 18 May 2015, http://www.grdc.com.au/Media-Centre/Hot-Topics/Sulfur-strategies-for-western-region/Details

More information

GRDC Update Papers: Review of sulfur strategy

GRDC Update Papers: Sulfur nutrition in canola—gypsum vs sulphate of ammonia and application timing

There is value in tissue testing before stem elongation to ensure the N:S ratio is less than 10:1 which normally means enough S for maximum N utilisation and minimal potential for S deficiency with additional applied N.

Subsoil S concentrations are a more reliable predictor of grain yield response to applied S. In most situations (depending on climate and soil type), the recommended values above which canola crops will not respond to applied S fertiliser are as follows:

- across all rainfall zones: 7.7 S/kg for 0–10 cm and 7.5 mg S/kg for 0–30 cm
- in high rainfall zones 11.0 S/kg for 0–10 cm and 9.5 mg S/kg for 0–30 cm [13]

5.6 Potassium

More information

GRDC Update Papers: Do we need to revisit potassium

GRDC Update Papers: Economics and management of P nutrition and multiple nutrient decline

An adequate supply of potassium (K) is important to provide plants with increased resistance to disease, frost and drought, as well as increased carbohydrate production. Canola crops take up large amounts of K during growth but most of it remains in the stubble, with only a small proportion removed in the grain.

Although soil tests, especially the balance of exchangeable cations, can provide a guide to the K level, tissue tests are the most reliable method to determine whether K fertiliser is needed. Avoid sowing K fertiliser with the seed; it could affect germination. [14]

N.B. The availability of K may be restricted early in the season if conditions are dry. Adequate K will need to be available early in the crop to ensure optimal growth. Be careful with applying K with the seed as it can have a salt effect, which can draw moisture away from the germinating seed.

5.7 Micronutrients

5.7.1 Zinc

Although canola is moderately susceptible to zinc (Zn) deficiency, it is rarely seen in paddocks with pH < 6 CaCl because many fertilisers contain trace levels of Zn, canola appears more effective at using soil Zn, and mild deficiency is difficult to identify.

Soils with pH 7.5 CaCl often express zinc deficiency in cereals and if yield responses to applied zinc are realized with cereals, it is likely that canola will also have a yield response in these same soils.

[13] GRDC (2015) Sulfur strategies for western region. GRDC Media Centre, 18 May 2015, http://www.grdc.com.au/Media-Centre/Hot-Topics/Sulfur-strategies-for-western-region/Details

[14] P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

What to look for

Symptoms listed below are a guide only and should be verified by plant nutrient test.

Paddock

- Plants are stunted and pale with areas of poorer growth alongside healthy, apparently normal plants giving the crop a patchy appearance (Figure 7).
- Worse symptoms are expected on sandy or alkaline grey clay soils (Figure 8), particularly if newly limed, and better on old windrows.
- Plants often improve on windrows.
- Stunted plants with pale green young leaves, particularly between leaf veins. (See Table 6 for conditions with similar symptoms.)
- Leaf blades bend down.
- Internodes are shortened as stems elongate.

Figure 7: Zinc deficiency in canola. (Photos: DAFWA)

Figure 8: Zinc deficiency appears as bronzing on the upper leaf surface and may occur in neutral to alkaline soils. (Photo: B. Holloway, SARDI)

What else could it be?

Table 6: Conditions that result in symptoms in canola similar to zinc deficiency

Condition	Similarities	Differences
Molybdenum deficiency	Smaller plants with pale green leaves; interveinal chlorosis	Molybdenum deficiency also causes scattered dead leaf spots; healthy and deficient plants are often intermixed; and leaves have scorched edges
Copper deficiency	Smaller plants with pale green leaves; interveinal chlorosis	Copper-deficient plants have numerous yellow specks that develop between veins of older leaves, progressing until the whole plant appears pale green

Where does it occur?

- Most sandy-surfaced soils required copper (Cu) and Zn when initially cleared for agriculture.
- Zinc is relatively immobile in soil and becomes unavailable to crops in dry soil.
- Where soil levels are marginal, Zn deficiency can be induced by applications of lime, increased N fertiliser, and Cu fertiliser.
- The use of root-pruning herbicides can induce Zn deficiency.
- Zinc deficiency is more common in high pH and clay soils.

Management strategies

- Use foliar spray (effective only in current season) or drilled soil fertiliser.
- Zinc foliar sprays need to be applied as soon as deficiency is detected to avoid irreversible damage.
- Because Zn is immobile in the soil, topdressing is ineffective; it is available to the plant only when the topsoil is wet.
- Mixing Zn throughout the topsoil improves availability through more uniform nutrient distribution.
- Drilling Zn deep increases the chances of roots being able to obtain enough molybdenum (Mo) in dry seasons.
- Seed treatment with Zn is used to promote early growth where root disease is a problem, but the level is lower than a plant needs in the current season.
- Zinc present in compound fertilisers often meets the current requirements of the crop.

How can it be monitored?

- A DTPA Zn soil test provides, at best, a rough guide to soil Zn status.
- Whole-shoot plant test provides a rough guide if paired good and poor samples are taken, but this should be confirmed with a youngest emerged blade (YEB) test.
- Whole shoots of young plants (40 days) below ~23 mg/kg and YEB levels below ~15 mg/kg indicate Zn deficiency. [15]

15 https://www.agric.wa.gov.au/mycrop/diagnosing-zinc-deficiency-canola DAFWA (2015) Diagnosing zinc deficiency in canola. Department of Agriculture and Food Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-zinc-deficiency-canola

5.7.2 Molybdenum

Role and deficiency symptoms

Molybdenum is important in enabling plants to convert nitrates from the soil into a usable form within the plant. Deficiency is more common in acid soil (pHCa <5.5) but is difficult to diagnose other than by a tissue test. Deficiency can be avoided by applying Mo at a rate of 50 g/ha every 5 years. The most common practice is application of 150 g/ha of the soluble form sodium molybdate (39% Mo) sprayed onto the soil surface. Molybdenum is compatible with pre-emergent herbicides and can be incorporated into the soil with sowing. [16]

Fertiliser requirements

Although fertilisers containing Mo can be used at sowing, the concentration of Mo they contain is less than recommended and they are more expensive than using sodium molybdate.

Molybdenum-treated single superphosphate applied during the pasture phase is cost-effective and it should supply enough Mo for the canola crop. [17]

5.7.3 Magnesium

In recent years, magnesium (Mg) deficiency has been reported in a number of seedling crops. As the crop grows and develops a deeper root system, the deficiency symptoms disappear because most soils have adequate Mg deeper in the profile. Low surface levels of Mg are probably due to low levels of sulfonylurea herbicide residues and the harvesting of subterranean clover hay, where large quantities of Mg are exported from the paddock.

Lime–dolomite blends can be used when liming acid soils if there is a history of deficiency symptoms, and other dry and foliar applied fertilisers are available. [18]

5.7.4 Calcium

Calcium (Ca) is important in plants because it assists in strengthening cell walls, thereby giving strength to plant tissues. Calcium is not readily transferred from older to younger tissue within a plant, so if a deficiency occurs it is first seen in the youngest stems, which wither and die, giving rise to the term ‘withertop’ or ‘Tipple Top’to describe Ca deficiency (Figure 9).

Calcium deficiency is not common but it can occur in acid soils, especially if the level of exchangeable Ca is low. The use of lime (calcium carbonate) on acid soils

---

16 P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

17 P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

18 P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

and gypsum on sodic soils has meant only an intermittent occurrence of withertop in canola. [19]

Calcium is relatively slow moving within the canola plant, this can explain some of the symptoms after a period of rapid growth.

Figure 9: Death of the canola flower head from calcium deficiency. (Photo: D. McCaffery, NSW DPI)

5.8 Toxicity

The most effective treatment for Al and Mn toxicity (Figure 10) is liming to raise the soil pH to >5.0. Lime rates depend on the pH to depth and the cation exchange capacity of the soil. Microfine lime is usually applied at 2.5–4.0 t/ha. Shallow incorporation of lime is sufficient to ameliorate surface soil acidity, but deep ripping is required to incorporate the lime, reduce soil strength and improve drainage where there is the more serious problem of subsoil acidity.

The sensitivity of canola to soil acidity has had beneficial spin-offs, in that it has forced Australian growers to implement liming programs before their soils become too acidic for less sensitive crop and pasture species.

There are breeding programs to improve the Al and Mn tolerance of Australian canola, by using both conventional technology and genetic engineering. The rationale for increasing the tolerance of canola to soil acidity is to broaden management options for growers while they implement liming programs. [20]

Boron deficiency can be confused with the phonological effect of applying herbicides such as Clethodim and Butroxydim.

[19] P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

[20] P Hocking, R Norton, A Good (1999) Crop nutrition. 10th International Rapeseed Congress, http://www.regional.org.au/au/gcirc/canola/p-05.htm

Figure 10: Symptoms of severe manganese toxicity in young canola on an acid soil.

More information

[Research paper: Risks of boron toxicity in canola and lupin by forms of boron application in acid sands of south-western Australia](#)

5.9 Nutrition effects on the following crop

Canola has provided the opportunity for more reliable responses to N in subsequent cereals by reducing cereal root diseases. [21] However, low yields and poor growth have been reported in crops following canola.

This is due to the depletion of soil microorganisms called arbuscular mycorrhizal fungi (AMF). They are beneficial soil fungi, assisting the uptake of P and Zn that would otherwise be unavailable to the crop. Canola does not need these fungi to help it take up P and Zn, so under canola the AMF population declines to a low level. To avoid this problem, follow canola with a short-fallow crop such as wheat or another cereal crop rather than pulses that depend on AMF. [22]

[21] R Norton, J Kirkegaard, J Angus, T Potter. Canola in rotations. Australian Oilseed Federation, http://www.australianoilseeds.com/__data/assets/pdf_file/0014/2705/Chapter_5_-_Canola_in_Rotations.pdf

[22] P Parker (2009) Nutrition and soil fertility. Ch. 7. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf